Design and Construction of a TPC with GEM Readout

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Overview

- Development of a TPC prototype
  - Optimisation of the fieldcage
  - Construction and first measurements
  - Readout electronics
- TPC simulation
TPC Prototype: Requirements

- 5T magnet at DESY: 280 mm bore
- SMD resistors as voltage divider
  ⇒ minimal pitch = 2.8 mm
- Materials with low density
  (radiation length)
- GEM readout from test TPC
  should be used
- 26 kV for drift field available
Optimisation of the field cage

Simulations of strip geometry with Maxwell 3D: copper strips on one or both sides, different ratios of strip width and distance with fixed pitch (2.8 mm)
TPC Prototype: Simulation

- Optimisation of the field cage
- Simulations of strip geometry with Maxwell 3D: copper strips on one or both sides, different ratios of strip width and distance with fixed pitch (2.8 mm)
TPC Prototype: Results of the Simulation

$\Delta E / E$

- $> +10^{-3}$
- $+/-10^{-4}$
- $-10^{-3}$

Copper strips:
width 2.3 mm
distance 0.5 mm
→ field with double-sided strips much better than with one-sided strips

$E_{parallel}$, strips on both sides

$E_{parallel}$, strips on one side
TPC Prototype: Construction

Ø = 260 mm

pitch = 2.8 mm

$R = 4.7 \Omega \text{ (SMD)}$

$U_{\text{max}} = 26 \text{kV}$

$l_{\text{drift}} = 26 \text{ cm}$

$E_{\text{max}} = 1000 \text{ V/cm}$
Al Foil, 0.05 mm

GFK, 0.25 mm

Aramid Honeycomb, 5 mm

4 x 0.125 mm Kapton

Epoxy Resin

Cu Strips, 0.03 mm, 2.8 mm Pitch

fraction of radiation length

altogether 1% radiation length

⇒ 3 % radiation length possible (TESLA)
TPC Prototype: First Results

First event

Homogeneous drift velocity

Drift Time [µs] vs. Position z' [cm]

Czech Technical University in Prague
Goal: Develop a test readout with 512 channels for our TPC

Requirements:
- fast preamplifiers to study time resolution
- small preamplifiers to allow compact readout design with small pads
- fast ADCs to match the preamplifier speed
- fast data acquisition to allow reasonable operation in test beam runs

Current Status:
- first signals with preamplifiers
- no full ADC instrumentation yet
MOKKA / GEANT ⇒ simulation of the whole detector

Our Goal: simple and efficient tool to simulate a TPC
⇒ analysis of the specific properties of a TPC, e.g.

- properties of electric and magnetic fields
- production and transfer of electric charges
- amplification in GEM structures
- ion backdrift
- pad response
TPC Simulation: Approach

- number of electrons along straight line
- clustering
- delta electrons
- without B field
- no 3D information

- dice number of electrons (Landau distribution)
- small track units
  -> approximation of clustering
- no delta electrons
- with B field
- 3D information
TPC Simulation: Status

simulated event, 3D view

Pad Plane B=0T

Pad Plane B=4T

pad size $2 \times 6 \text{ mm}^2$

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Conclusion

- TPC prototype for use in magnet constructed
- First cosmic muons observed, homogenous drift velocity
- Development of new readout electronics for use in test beams ongoing
- Basic simulations of 3D event in TPC
Backup TPC Construction

$\varnothing = 260 \text{ mm}$

pitch = 2.8 mm

$R = 4.7 \text{ M}\Omega \text{ (SMD)}$

$U_{\text{max}} = 26 \text{ kV}$

$\ell_{\text{drift}} = 26 \text{ cm}$

$E_{\text{max}} = 1000 \text{ V/cm}$

xz profile of the TPC prototype
TPC Fieldcage

xy profile of the field cage
test of dielectric strength of the sandwich structure:

\[ U = 30 \text{ kV} \text{ one week without trip} \]

final strip design: inside: width 2.0 mm, distance 0.8 mm
outside: width 1.8 mm, distance 1.0 mm
## ADCs

### Backup: ADCs

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Requirements</th>
<th>Status</th>
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<tbody>
<tr>
<td>bus type</td>
<td>VME</td>
<td>VME</td>
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<tr>
<td>resolution</td>
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<td>sampling rate</td>
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<td>channels per module</td>
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<tr>
<td>channels total</td>
<td>512</td>
<td>20</td>
</tr>
</tbody>
</table>

⇒ no solution yet!

But 32 channel ADC from TU Munich (Igor Konorov) is tested!
Tracks

1. read PHYTHIA event \( \Rightarrow E, \vec{p}, m \)
2. for each particle: dice number \( n \) of electrons per cm (Landau distribution)
3. dice coordinates of electrons on each part of the track along \( \vec{p} \) (uniformly distributed)
4. calculate energy \( E' = E - n \cdot 26 \text{ eV} \)
5. repeat steps 2-4 until particle has left the TPC or \( E' = m \)

Drift

1. parametrisation of gas properties \( \Rightarrow v_D(\vec{E}), d_1(\vec{E}), d_t(\vec{E}, \vec{B}) \)
2. dice according to the parameters (Gaussian distribution)